4 Years B.S. Programme in Mathematics and Computing

Offered by

Department of Mathematics, IIT Patna

Bachelor of Science (Mathematics and Computing)

The Department of Mathematics would start a four year Bachelor of Science (Mathematics and Computing) Programme in 2020. This programme is designed to cover a wide range of courses with the motive that the students would be well equipped with the basic techniques of mathematics and computer science. Towards this, they will have the access of modern laboratory and computational facilities and during the study they will have assignments involving the same. In project work and on the Bachelor's Thesis the students will have the opportunity to apply their knowledge to fore front areas of the subject. It is expected and desired that a large fraction of B.S. passed out students would find their places in industries (placement) and academia (for higher studies in various prestigious institutes/universities) all over the world.

Admission Procedure:

The admission to the four year (Eight Semester) B.S. (Mathematics and Computing) programme will be through the Joint Entrance Examination (JEE- Advance) conducted by IITs.

Semester-wise Course Structure:

SEMESTER I

Code	Course Name	L	T	P	C
CE111	**Engineering Drawing**	1	0	3	5
EE101	**Electrical Sciences**	3	1	0	8
HS103	**Communicative English for Engineers**	2	0.5	1	6
MA101	**Mathematics – I**	3	1	0	8
ME110	**Workshop – I**	0	0	3	3
PH103	**Physics – I**	3	1	0	8
PH110	**Physics Laboratory**	0	0	3	3
		12	3.5	10	41

SEMESTER II

Code	Course Name	L	T	P	C
CB102 and CE102	**Biology and Environmental Studies**	3	0	0	6
CH103	**Introductory Chemistry**	3	1	0	8
CH110	**Chemistry Laboratory**	0	0	3	3
CS102	**Programming and Data Structures**	3	0	0	6
CS112	**Programming and Data Structures Laboratory**	0	0	3	3
EE103	**Basic Electronics Laboratory**	0	0	3	3
MA102	**Mathematics-II**	3	1	0	8
ME102	**Engineering Mechanics**	3	1	0	8
		15	3	9	45

SEMESTER III

Code	Course Name	L	T	P	C
CS2XX	**Digital Logic**	3	0	0	6
HS2XX	**HSS Elective – I**	3	0	0	6
MA211	**Algorithms**	3	0	0	6
MA219	**Algorithm Laboratory**	0	0	3	3
MA213	**Discrete Mathematics**	3	0	0	6
MA215	**Real Analysis**	3	0	0	6
MA217	**Algebra**	3	0	0	6
		18	0	3	39

SEMESTER IV

Code	Course Name	L	T	P	C
HS2XX	**HSS Elective – II**	3	0	0	6
XX2XX	**Open Elective I**	3	0	0	6
MA216	**Topology and Geometry**	3	0	0	6
MA218	**Complex Analysis**	3	0	0	6
MA220	**Numerical Linear Algebra**	3	0	0	6
MA225	**Probability Theory & Random Process**	3	1	0	8
MA227	**Computational Lab (Numerical Linear Algebra)**	0	0	3	3
		18	1	3	41

SEMESTER V

Code	Course Name	L	T	P	C
XX3XX	**Open Elective – III**	3	0	0	6
MA301	**Differential Equations**	3	0	0	6
MA303	**Functional Analysis**	3	0	0	6
MA305/ CS321	**Computer Architecture**	3	0	0	6
MA307/ CS322	**Computer Architecture Lab**	0	0	3	3
MA309	**Optimization Techniques**	3	0	0	6
MA311	**Theory of computation**	3	0	0	6
		18	0	3	39

SEMESTER VI

Code	Course Name	L	T	P	C
HS3XX	**HSS Elective – III**	3	0	0	6
MA312	**Number Theory**	3	0	0	6
MA314	**Numerical Analysis**	3	0	0	6
MA3XX	**Departmental Elective-I**	3	0	0	6
MA316	**Mathematical Statistics**	3	0	0	6
MA318	**Computational Lab (For NA & Statistics)**	0	0	3	3
		15	0	3	33

SEMESTER VII

Code	Course Name	L	T	P	C
XX4XX	**Open Elective – III**	3	0	0	6
MA401	**Convex Optimization**	3	0	2	8
MA4XX	**Departmental Elective-II**	3	0	0	6
MA4XX	**Departmental Elective – III**	3	0	0	6
MA497	**Project-I**	0	0	6	6
		12	0	8	32

SEMESTER VIII

Code	Course Name	L	T	P	C
MA4XX	**Departmental Elective-IV**	3	0	0	6
MA4XX	**Departmental Elective- V**	3	0	0	6
MA4XX	**Departmental Elective-VI**	3	0	0	6
MA498	**Project-II**	0	0	12	12
		9	0	12	30

Total Credit =300

Department Electives: This list courses contains the existing course for the purpose of electives. Further, as and when a course is approved, will be added to the list. Department may allow courses from other departments (on agreement of offering department) as department elective if the course is needed and suitable for the candidates of the program.

List of Electives for Semester VI:

MA452	**Discrete Differential Geometry**	**3**	**0**	**0**	**6**
MA332	**Introduction to Mathematical Biology**	**3**	**0**	**0**	**6**

List of Electives for Semester VII:

MA 527	**Algebraic Topology**	**3**	**0**	**0**	**6**
MA 531	**Control Theory**	**3**	**0**	**0**	**6**
MA 533	**Graph Theory**	**3**	**0**	**0**	**6**
MA 535	**Introduction to Coding Theory**	**3**	**0**	**0**	**6**
MA 539	**Mathematical Modeling**	**3**	**0**	**0**	**6**
MA 541	**Statistical Inference**	**3**	**0**	**0**	**6**
MA515	**Cryptography**	**3**	**0**	**0**	**6**
MA543	**Fields and Galois theory**	**3**	**0**	**0**	**6**
MA503	**Discrete Structures**	**3**	**0**	**0**	**6**
MA545	**Introduction to Algebraic Geometry**	**3**	**0**	**0**	**6**

List of Electives for Semester VIII:

MA 526	**Differential Manifolds**	**3**	**0**	**0**	**6**
MA 528	**Differential Topology**	**3**	**0**	**0**	**6**
MA 530	**Fuzzy Sets and Systems**	**3**	**0**	**0**	**6**
MA 532	**Introduction to Biomathematics**	**3**	**0**	**0**	**6**
MA 534	**Operators on Hilbert Spaces**	**3**	**0**	**0**	**6**
MA 536	**Rings and Modules**	**3**	**0**	**0**	**6**
MA 538	**Statistical Decision Theory**	**3**	**0**	**0**	**6**
MA 540	**Wavelets Transform**	**3**	**0**	**0**	**6**
MA508	**Fuzzy sets and Artificial Intelligence**	**3**	**0**	**0**	**6**
MA544	**Introduction to Homological Algebra**	**3**	**0**	**0**	**6**

DETAIL COURSE CONTENT

Course Name	Mathematics – I
Course Number	MA101
Course Credit	3-1-0-8
Prerequisite	

Properties of real numbers. Sequences of real numbers, montone sequences, Cauchy sequences, divergent sequences. Series of real numbers, Cauchy's criterion, tests for convergence. Limits of functions, continuous functions, uniform continuity, montone and inverse functions. Differentiable functions, Rolle's theorem, mean value theorems and Taylor's theorem, power series. Riemann integration, fundamental theorem of integral calculus, improper integrals. Application to length, area, volume, surface area of revolution. Vector functions of one variable and their derivatives. Functions of several variables, partial derivatives, chain rule, gradient and directional derivative. Tangent planes and normals. Maxima, minima, saddle points, Lagrange multipliers, exact differentials. Repeated and multiple integrals with application to volume, surface area, moments of inertia. Change of variables. Vector fields, line and surface integrals. Green's, Gauss' and Stokes' theorems and their applications.

Text Books:

1. G. B. Thomas and R. L. Finney, Calculus and Analytic Geometry, 6th Ed/ 9th Ed, Narosa/ Addison Wesley/ Pearson, 1985/ 1996.
2. T. M. Apostol, Calculus, Volume I, 2nd Ed, Wiley, 1967.
3. T. M. Apostol, Calculus, Volume II, 2nd Ed, Wiley, 1969.

Reference Books:

1. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 5th Ed, Wiley, 1999.
2. J. Stewart, Calculus: Early Transcendentals, 5th Ed, Thomas Learning (Brooks/ Cole), Indian Reprint, 2003.

Course Name	Mathematics – II
Course Number	MA102
Course Credit	3-1-0-8
Prerequisite	Nil

Linear Algebra: Vector spaces (over the field of real and complex numbers). Systems of linear equations and their solutions. Matrices, determinants, rank and inverse. Linear transformations. Range space and rank, null space and nullity. Eigenvalues and eigenvectors. Similarity transformations. Diagonalization of Hermitian matrices. Bilinear and quadratic forms.

Ordinary Differential Equations: First order ordinary differential equations, exactness and integrating factors. Variation of parameters. Picard's iteration. Ordinary linear differential equations of n-th order, solutions of homogeneous and non-homogeneous equations. Operator method. Method of undetermined coefficients and variation of parameters.

Power series methods for solutions of ordinary differential equations. Legendre equation and Legendre polynomials, Bessel equation and Bessel functions of first and second kind.

Systems of ordinary differential equations, phase plane, critical point, stability.

Text Books:

1. K. Hoffman and R. Kunze, Linear Algebra, Prentice Hall, 1996.
2. T. M. Apostol, Calculus, Volume II, 2nd Edition, Wiley, 1969.
3. S. L. Ross, Differential Equations, 3rd Edition, Wiley, 1984.
4. E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall, 1995.
5. W.E. Boyce and R.C. DiPrima, Elementary Differential Equations and Boundary Value Problems, 7th Edition, Wiley, 2001.

Reference Books:

1. E. Kreyszig, Advanced Engineering Mathematics, 9th Edition, Wiley, 2005.

Course Name	Algorithms
Course Number	MA211
Course Credit	3-0-0-6
Prerequisite	

Model of Computations: RAM Model of computation, uniform cost model, logarithmic cost model .

Complexity Analysis: Big O, omega, theta notations, solving recurrence relation

Data Structure: binary search trees, AVL trees and red-black trees, B-trees, hashing, Priority queues, Heaps.

Sorting algorithms: Merge sort, Quick sort, Heap sort, Randomized quick sort, Lower bound of comparison based sorting, Counting sort, Radix sort, Bucket sort.

Algorithm design techniques: Greedy, Divide and Conquer, Dynamic Programming .

Graph Algorithms: BFS and DFS, Minimum spanning trees- Kruskal and Prim algorithm, Shortest Path- Dijkstra, Bellman-Ford, Johnson algorithm, Network flow- Ford-Fulkerson algorithm .

NP-Completeness: Class P, NP, NP-hard and NP-complete, Examples of NP-complete problems.

Text Books/References:

1. "Data Structures and Algorithms in C++" by M. A. Weiss, Addison-Wesley
2. "Algorithm Design" by J. Kleinberg and Eva Tardos, Pearson Education
3. "Introduction to Algorithms" by T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, Prentice Hall India.
4. "The Design and Analysis of Computer Algorithms" by A. Aho, J. E. Hopcroft and J. D. Ullman, Addison-Wesley.

Course Name	Algorithm Laboratory
Course Number	MA219
Course Credit	0-0-3-3
Prerequisite	

The problems to be solved should involve all the algorithm designing techniques that are covered in the theory class. The exact set of problems is to be decided by the instructor. The programming language is also to be decided by the instructor.

Course Name	Discrete Mathematics
Course Number	MA213
Course Credit	3-0-0-6
Prerequisite	

Mathematical Logic and Proofs: Propositional logic and equivalences, Predicate and Quantifiers, Introduction to Proofs, Proof methods

Sets, Relations and Functions: Relations and their properties, Closure of Relations, Order Relations, Equivalence relations, POSets and Lattices

Counting Techniques: Permutations and Combinations, Binomial coefficients, Pigeonhole principle, Double counting, Principle of Inclusion-Exclusion, Recurrence relations and its solution, Divide and Conquer, Generating functions

Graph Theory: Basic definitions, Trees, Connectivity, Spanning trees, Shortest Path Problems, Eulerian and Hamiltonian graphs, Planar graphs, Graph Coloring

Boolean Algebra: Boolean functions, Logic gates, Simplification of Boolean Functions, Boolean Circuits

Text Books:

1. Discrete Mathematics and Its Applications by K. H. Rosen, Tata McGraw-Hill

Reference Books:

1. Basic Techniques of Combinatorial Theory by D. I. A. Cohen, John Wiley & Sons
2. Introduction to Graph Theory by D. B. West, Pearson Prentice Hall
3. Elements of Discrete Mathematics by C. L. Liu, Tata McGraw-Hill
4. Invitation to Discrete Mathematics by J. Matousek and J. Nesetril, Oxford University Press

Course Name	Real Analysis
Course Number	MA215
Course Credit	3-0-0-6
Prerequisite	

Review of Real number system: Completeness property, Archimedian property, Denseness of rationals and irrationals, Countable and uncountable, Cardinality, Zorn's lemma.

Metric spaces: Open sets, Closed sets, Continuous functions, Completeness, Cantor intersection theorem, Baire category theorem, Compactness, Totally boundedness, Finite intersection property.

Functions of several variables: Differentiation, inverse and implicit function theorems.

Rlemann-Stieitjes integral: Definition, existence, and properties of the integral

Sequence and Series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. Equicontinuity, Ascoli's Theorem.

Text/Reference Books:

1. T.M. Apostol, "Mathematical Analysis", Narosa Publishing House, 2002.
2. K. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
3. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill, 1976.

Course Name	Algebra
Course Number	MA217
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Groups, subgroups, normal subgroups, Examples: permutation groups, cyclic groups, dihedral groups, matrix groups.

Homomorphisms, quotient groups, Isomorphisms. Cayley's theorem, groups acting on sets, Sylow theorems and applications, direct products, finitely generated abelian groups, Structure Theorem for finite abelian groups.

Rings, fields, integral domain, basic properties of rings, units, ideals, homomorphisms, quotient rings, prime and maximal ideals, fields of fractions, Euclidean domains, principal ideal domains and unique factorization domains, polynomial rings.

Text Books:

1. D. Dummit and R. Foote, Abstract Algebra, 3rd edition, Wiley, 2004.
2. J. A. Gallian, Contemporary Abstract Algebra, 4th ed., Narosa, 1999.

Reference Books:

1. M. Artin, Algebra, Prentice Hall of India, 1994.
2. T. T. Moh, Algebra, World Scientific, 1992.
3. S. Lang, Undergraduate Algebra, 2nd Ed., Springer, 2001.
4. S. R. Nagpaul and S. K. Jain, Topics in Applied Abstract Algebra, Amer. Math. Soc., First Indian Edition, 2010.
5. J. B. Fraleigh, A First Course in Abstract Algebra Paperback, Addison-wesley 1967.
6. Derek J. S. Robinson, Abstract Algebra: An introduction with Applicationsy, De Gruyter, 2nd Edition, 2015.
7. Paul B. Garrett, Abstract Algebra, Chapman and Hall/CRC, 1st edition, 2007.

Course Name	Topology and Geometry
Course Number	MA216
Course Credit	3-0-0-6
Prerequisite	

Review of two-dimensional coordinate Geometry (Polar coordinates of parabola, ellipse and hyperbola, polar equations).
Spheres: Equation, plane section and intersection of two spheres, sphere through a circle, tangent plane angle of intersection of two spheres, coaxial system and orthogonal system.

Cone and Cylinder: Cone and Cylinder with given base, plane passing through vertex of cone, tangent lines and planes, right circular cone and cylinder.

Surfaces: Ruled surfaces, generating lines of a hyperboloid of one sheet and hyperbolic paraboloid and its properties, principal elliptic section. Standard equation of central conicoids and paraboloids, tangent lines and planes, polar planes and lines, enveloping cones and cylinders, section with given center. Normals to central conicoids. Cones passing through normals, conjugate diameters of an ellipsoid and its properties.

Introduction to topology: Topological Spaces, Basis for a Topology, Product Topology, Subspace Topology, Closed Sets and Limit Points, Continuous functions, Quotient Topology.

Connectedness and Compactness: Connected Spaces, Components and Local Connectedness, Compact Spaces, Limit Point Compactness, Local Compactness.

Separation Axioms: The Countability Axioms, The Separation Axioms, Normal Spaces, The Urysohn Lemma, The Urysohn Metrization Theorem.

Textbook:

1. N Saran and R S Gupta: Analytic Geometry of Three Dimensions, Pothishala Pvt. Ltd. Allahabad.
2. William H McCrea: Analytic Geometry of Three Dimensions, Dover, 2nd Rev Ed.
3. George Salmon: A treatise on Analytic Geometry of Three Dimensions, University of Michigan Library (2006).
4. Shanti Narayan and P.K. Mittal: Analytic Solid Geometry, Paperback, S. Chand.
5. James R. Munkres, Topology, PHI, Second Edition (2011)
6. I M Singer and J A Thorpe: Lecture notes on Elementary Topology and Geometry, Springer; Reprint 1976.

Course Name	Complex Analysis
Course Number	MA218
Course Credit	3-0-0-6
Prerequisite	

Complex Numbers, Regions in the Complex, Analytic Functions, Mappings, Limits, Continuity, Derivatives, Cauchy-Riemann Equations, Harmonic Functions, Reflection Principle, Elementary Functions, Branch and Branch Cut, Contour Integrals, Upper Bounds for Moduli of Contour Integrals, Cauchy-Goursat Theorem, Simply and Multiply Connected Domains, Cauchy Integral Formula, Liouville's Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle, Taylor Series, Laurent Series, Power Series, Residues and Poles, Cauchy's Residue Theorem, The Three Types of Isolated Singular Points, Residues at Poles, Zeros of Analytic Functions, Zeros and Poles, Behavior Near Isolated Singular Points, Evaluation of Improper Integrals, Jordan's Lemma, Indented Paths, An Indentation Around a Branch Point, Integration Along a Branch Cut, Definite integrals involving Sines and Cosines, Argument Principle, Rouche's Theorem, Inverse Laplace Transforms, Mapping by Elementary Functions Linear Transformations, Linear Fractional Transformations, Inverse Points, Riemann Surfaces, Conformal Mapping, Riemann Zeta Function, Riemann Hypothesis.

Text Books:

1. Fischer, Wolfgang, Lieb, IngoA Course in Complex Analysis, Springer-Verlag, (2012).
2. Complex Variables and Applications: James Ward Brown and Ruel V. Churchill, 8th Edition, McGraw Hills.

Reference Books:

1. Joseph L. Taylor, Complex Variables - American Mathematical Society, 2011.
2. Mark J. Ablowitz, A. S. Focas, Complex Variables: Introduction and Applications Second Edition (Cambridge Texts in Applied Mathematics) 2nd Edition, Cambridge University Press; 2 edition, 2003.
3. Edward C. Titchmarsh, The Theory of Functions, Oxford University Press; 2 edition, 1976.
4. John B. Conway, Functions of One Complex Variable I, Springer-Verlag New York, 1978.

Course Name	Numerical Linear Algebra
Course Number	MA220
Course Credit	3-0-0-6
Prerequisite	

Review of basic concepts from linear Algebra; direct methods for solving linear systems; vector and matrix norms; condition numbers; least squares problems; iterative methods for solving linear systems - Jacobi, Gauss Seidel, SOR and their convergence; projection methods - general projection method, steepest descent, MR Iteration, RNSD method and their convergence; orthogonalization; singular value decomposition; numerical computation of eigenvalues and eigenvectors; Introduction to Krylov subspace methods - Arnoldi's method, GMRES method, Conjugate gradient algorithm, Lanczos Algorithm and convergence check for Krylov subspace methods, Preconditioned CG, ILU preconditioner.

Text Books:

1. Iterative Methods for Sparse Linear Systems (Textbook), Yousef Saad, SIAM 2003
2. Matrix Computations (Textbook), Gene H. Golub, Charles, F. Van Loan, John Hopkins University Press, 1996
3. Matrix iterative Analysis, R. S. Varga, Prentice Hall 1962
4. Introduction to matrix computation, Gilbert W. Stewart, Academic Press 1973
5. Numerical Linear Algebra, L.N. Trefethen, D. Bau, SIAM, 1997
6. Fundamentals of Matrix Computations, Watkins, Wiley-Interscience, 2010

Course Name	Probability Theory and Random Process
Course Number	MA225
Course Credit	3-1-0-8
Prerequisite	Nil

Axiomatic construction of the theory of probability, independence, conditional probability, and basic formulae, random variables, probability distributions, functions of random variables; Standard univariate discrete and continuous distributions and their properties, mathematical expectations, moments, moment generating function, characteristic functions; Random vectors, multivariate distributions, marginal and conditional distributions, conditional expectations; Modes of convergence of sequences of random variables, laws of large numbers, central limit theorems. Definition and classification of random processes, discrete-time Markov chains, Poisson process, continuous-time Markov chains, renewal and semi-Markov processes, stationary processes, Gaussian process, Brownian motion, filtrations and martingales, stopping times and optimal stopping.

Text Books:

1. G. R. Grimmett and D. R. Stirzaker, Probability and Random Processes, Oxford University Press, 2001.
2. P. G. Hoel, S. C. Port and C. J. Stone, Introduction to Probability Theory, Universal Book Stall, 2000.
3. W. Feller, An Introduction to Probability Theory and its Applications, Vol. 1, 3rd Edition, Wiley, 1968.
4. K. S. Trivedi, Probability and Statistics with Reliability, Queuing, and Computer Science Applications, Prentice Hall of India, 1998.
5. A. Papoulis and S. Unnikrishna Pillai, Probabilities, Random Variables and Stochastic Processes, 4th Edition, Tata McGraw-Hill, 2002.
6. S.M. Ross, Stochastic Processes, 2nd Edition, Wiley, 1996.
7. J. Medhi, Stochastic Processes, New Age International, 1994.

Course Name	Computational Lab (Numerical Linear Algebra)
Course Number	MA227
Course Credit	0-0-3-3
Prerequisite	

Numerical Analysis:- Introduction to Matlab, Plotting of function and Surface, Computation of Roots by Newton Raphson Methods, Finding Solution of a System based on Gauss Elimination and Gauss Jacobi methods, Finding Numerical Solutions of ODE by Finite Difference Method

Probability & Statistics:- Random numbers, Generations of discrete random variables, Generations of continuous random variables

Text Books:

1. Programming and Engineering Computing with MATLAB 2019, 1st Edition, Huei-Huang Lee
2. MATLAB with Applications to Engineering, Physics and Finance, 1st Edition, David Baez-Lopez, CRC Press
3. Computational Partial Differential Equations Using MATLAB, 2nd Edition, Jichun Li, Yi-Tung Chen, CRC Press
4. Simulation, Fifth Edition, Sheldon M Ross, Elsevier

Course Name	Differential Equations
Course Number	MA301
Course Credit	3-0-0-6
Prerequisite	

ODE: Review of ODEs, Existence and Uniqueness of solution to system of equations and nth order equation, Self-adjoint Eigenvalue problems on a finite interval, Oscillation and Comparison theorems for second order linear equations and applications, Green's function, Existence and Uniqueness for BVP, Singular Self-adjoint BVPs for second order equations, Singular self adjoint BVPs for nth Order Equations, Non-self adjoint BVPs.

PDE: Introduction to PDE and the classification of PDEs (Linear, Nonlinear, Quasi Linear), Lagrange's and Charpit's Method, Second order PDEs and Their Classification, Method of Separation of Variables, Method of Characteristics, D'Alembert Solution, Duhamel's principle. Maximum Principle and existence theorems, Fourier series, Fourier Transform, Laplace Transform and their application, Green's function, Green's function for Heat, Wave and Poisson equation.

Text Books:

1. Earl A. Coddington, Norman Levinson, Theory of Ordinary Differential Equations, Tata McGraw Hill Education Private Limited, New Delhi, 1972.
2. Ian Sneddon, Elements of Partial Differential Equations, McGraw-Hill International Editions, 1957.

Reference Books:

1. Mark A. Pinsky, Partial Differential Equations and Boundary-Value Problems with Applications, American Mathematical Society, 2013.
2. Geroge F. Simmons, Differential Equations with Applications and Historical Notes, 2nd Edition, Tata McGraw Hills, 2010.
3. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall, 1961.
4. Myint U. Tyn, Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, Birkhauser, 4th Edition.
5. T. Amarnath, An Elementary Course in Partial Differential Equations, Narosa, 2nd Edition.
6. Myint U. Tyn, Ordinary differential equations, Elsevier North-Holland, 1978.

Course Name	Functional Analysis
Course Number	MA303
Course Credit	3-0-0-6
Prerequisite	

Normed spaces, Banach spaces, Properties of Banach spaces, Linear operators, Bounded linear operators, Linear operators and functionals on Banach spaces, Dual space; Inner product space. Hilbert spaces, Properties of inner product spaces, Orthogonal complements and direct sums, Orthonormal sets and sequences, Total orthonormal sets, Legendre, Hermite and Laguerre polynomials, Representation of functionals on Hilbert spaces, Adjoint operator, Self-Adjoint, Unitary and Normal operators.

Text Books:

1. G. J. O. Jameson, Topology and normed spaces, Chapman and Hall, London, 1974.
2. Erwin Kreyszig, Introductory Functional Analysis With Applications, John Wiley & Sons 1978.
3. Nair, M. T., Functional Analysis: A First Course, PHI Pvt. Ltd, 2004

Reference Books:

1. Balmohan Vishnu Limaye, Functional Analysis, New Age International Publishers, 2008.
2. S. Kesavan, Functional Analysis, Springer, 2009.
3. Walter Rudin, Functional Analysis, McGraw-Hill, 1991.

Course Name	Optimization Techniques
Course Number	MA309
Course Credit	3-0-0-6
Prerequisite	Nil

Linear programming: Introduction and Problem formulation, Concept from Geometry, Geometrical aspects of LPP, Graphical solutions, Linear programming in standard form, Simplex, Big M and Two Phase Methods, Revised simplex method, Special cases of LPP.

Duality theory: Dual simplex method, Sensitivity analysis of LP problem, Transportation, Assignment and travelling salesman problem.

Integer programming problems: Branch and bound method, Gomory cutting plane method for all integer and for mixed integer LPP.

Theory of games: saddle point, linear programming formulation of matrix games, two-person zero-sum games with and without saddle-points, pure and mixed strategies, graphical method of solution of a game, solution of an game by simplex method. Computational complexity of the Simplex algorithm, Karmarkar's algorithm for LPP.

Acquaintance to softwares like TORA and MATLAB.

Text Books:

1. Hamdy A. Taha, Operations Research: An Introduction, Eighth edition, PHI, New Delhi (2007).
2. S. Chandra, Jayadeva, Aparna Mehra, Numerical Optimization with Applications, Narosa Publishing House (2009).
3. A. Ravindran, D.T. Phillips, J.J. Solberg, Operation Research, John Wiley and Sons, New York (2005).
4. M. S. Bazaraa, J. J. Jarvis and H. D. Sherali, Linear Programming and Network Flows, 3rd Edition, Wiley (2004).

Reference Books:

1. D. G. Luenberger, Linear and Nonlinear Programming, 2nd Edition, Kluwer, (2003).
2. S. A. Zenios (editor), Financial Optimization, Cambridge University Press (2002).
3. F. S. Hiller, G. J. Lieberman, Introduction to Operations Research, Eighth edition, McGraw Hill (2006).

Course Name	Theory of Computation
Course Number	MA311
Course Credit	3-0-0-6
Prerequisite	

Regular Languages: Finite Automata-Deterministic and Nondeterministic, regular operations, Regular Expressions, Equivalence of DFA, NFA and Res, Nonregular Languages and pumping lemma

Context-Free Languages: Context-Free Grammars, Chomsky Normal Form, Pushdown Automata, Noncontext-Free Languages and pumping lemma, Deterministic Context-Free Languages

Turing Machines: Definition of TM and its variants, Decidability, Reducibility.

Complexity Theory: Time complexity and Space Complexity.

Text Books:

1. Introduction to the Theory of Computation, by Michael Sipser,
2. Computational Complexity, by Christos H. Papadimitriou, Addison-Wesley publishers.
3. Computational Complexity: A Modern Approach, by Sanjeev Arora and Boaz Barak.

Course Name	Number Theory
Course Number	MA312
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Divisibility in integers, basic algebra of infinitude of primes, discussion of the prime number theorem, Fundamental theorem of arithmetic, Dirichlet's theorem (without proof).

Arithmetic functions, Mobius inversion formula, Structure of units modulo n, Euler's phi function. Primitive roots and indices, group of units.

Congruences, Fermat's theorem and Euler's theorem, Wilson's theorem, linear congruences, Simultaneous linear congruences, Chinese Remainder Theorem, Simultaneous non-linear congruences.

Quadratic residues, law of quadratic reciprocity, binary quadratics forms, Fermat's two square theorem, Sum of three squares, Lagrange's four square theorem.

Continued fractions, rational approximations, Liouville's theorem, discussion of Roth's theorem, transcendental numbers, transcendence of "e" and "pi".

Diophantine equations: Brahmagupta's equation (also known as Pell's equation), Fermat's method of descent, discussion of the Mordell's equation.

Text Books:

1. David M. Burton, Elementary Number Theory, 6th Edition, McGrow Hill Higher Education, 2007.

References

1. W. W. Adams and L.J. Goldstein, Introduction to the Theory of Numbers, 3rd ed., Wiley Eastern, 1972.
2. A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge, 1984.
3. I. Niven and H.S. Zuckerman, An Introduction to the Theory of Numbers, 5th Ed., Wiley, New York, 2008.
4. Thomas Koshy, Elementary Number Theory with Applications, 2nd Edition, Academic Press, 2007.

Course Name	Numerical Analysis
Course Number	MA314
Course Credit	3-0-0-6
Prerequisite	

Introduction to Floating Point System, Sensitivity and Conditioning of a function and matrix, Fixed Point Iteration, Secant Method, Solution of Nonlinear System based on Newton Raphson Method, Sufficient condition for convergence of solution, Introduction of Direct (Gauss Elimination, Pivot, LU decomposition) and Iterative Methods (Gauss Jacobi and Seidel), Matrix norm dependent Sufficient condition for convergent solution, Conditioning and Residual Errors, Gerschgorin Circle, Eigen Value and Vector Computation, Basic of Interpolation and Integration (Trapezoidal, Simpson, Quadrature Methods) and Differentiation, Polynomial approximation of a function based on L-\infty and L_2 norms and consequences, Best Polynomial Approximation

Consistency and Stability of IVP and BVP, Lax Equivalence Theorem, Runge Kutta Method, M matrix based Stability, Error Analysis, Extension of Difference schemes for ODEs and PDEs (Convection diffusion reaction problems)

Text Books:

1. Michael T. Heath, Scientific Computing, An Introductory Survey, Tata McGraw Hill.
2. Endre Suli and David F. Mayers, An Introduction to Numerical Analysis, Cambridge Univ Press.
3. M. K. Jain, S.R.K. Iyenger, RK Jain, Numerical Methods, For Scientific and Engineering Computation, New Age Publisher.
4. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley & Sons.
5. A Theoretical Introduction to Numerical Analysis, 1st Edition, By Victor S. Ryaben'kii, Semyon V. Tsynkov, Chapman and Hall/CRC.

Course Name	Mathematical Statistics
Course Number	MA316
Course Credit	3-0-0-6
Prerequisite	

Ordered Statistics, probability distributions of Sample Range, Minimum and Maximum order Statistics. Random Sampling, Sampling distributions: Chi-square, T, F distributions.

Point Estimation: Sufficiency, Factorization theorem, Consistency, Moment method of estimation, Unbiased Estimation, Minimum Variance Unbiased Estimator and their properties, Rao-Cramer lower bound, Rao-Blackwellization, Fisher Information, Maximum Likelihood Estimator and properties, Criteria for evaluating estimators: Mean squared error.

Interval Estimation: Coverage Probabilities, Confidence level, Sample size determination, Shortest Length interval, Pivotal quantities, interval estimators for various distributions.

Testing of Hypotheses: Null and Alternative Hypotheses, Simple hypothesis, Composite hypothesis, Test Statistic, Critical region, Error Probabilities, Power Function, Level of Significance, Neyman-Pearson Lemma, One and Two Sided Tests for Mean, Variance and Proportions, One and Two Sample T-Test, Pooled T-Test, Paired T-Test, Chi-Square Test, Contingency Table Test, Maximum Likelihood Test, Duality between Confidence Intervals.

Bayesian Estimation: Prior and Posterior Distributions, Quadratic Loss Function, Posterior Mean, Bayes Estimates for well Known Distributions (Normal, Gamma, Exponential, Binomial, Poisson, Beta etc.)

Text Books:

1. Mathematical Statistics with applications, Kandethody M. Ramachandran, Chris P. Tsokos, Academic Press, 2009
2. Probability and Statistics in Engineering, William W. Hines, Douglas C. Montgomery, David M. Goldsman, Connie M. Borror, John Wiley & Sons; 4th Edition Edition, 2003.
3. Introduction to Mathematical Statistics, Robert V. Hogg, Joseph W. McKean, Allen T. Craig, 7th Edition, Pearson, 2012

Reference Books:

1. Statistical Inference, G. Casella and R.L. Berger, Duxbury Advanced Series, Second Edition, 2007

Course Name	Computational Lab (For NA & Statistics)
Course Number	MA318
Course Credit	0-0-3-3
Prerequisite	

Numerical Analysis:- Introduction to Matlab, Plotting of function and Surface, Computation of Roots by Newton Raphson Methods, Finding Solution of a System based on Gauss Elimination and Gauss Jacobi methods, Finding Numerical Solutions of ODE by Finite Difference Method

Probability & Statistics:- Random numbers, Generations of discrete random variables, Generations of continuous random variables

Text Books:

1. Programming and Engineering Computing with MATLAB 2019, 1st Edition, Huei-Huang Lee
2. MATLAB with Applications to Engineering, Physics and Finance, 1st Edition, David Baez-Lopez, CRC Press
3. Computational Partial Differential Equations Using MATLAB, 2nd Edition, Jichun Li, Yi-Tung Chen, CRC Press
4. Simulation, Fifth Edition, Sheldon M Ross, Elsevier, 2013

Course Name	Convex Optimization
Course Number	MA401
Course Credit	3-0-2-8
Prerequisite	Nil

Introduction to nonlinear programming, Convex Sets, Convex Functions and their properties.

Unconstrained optimization of functions of several variables: Classical techniques. Numerical methods for unconstrained optimization: One Dimensional Search Methods, Golden Section Search and Fibonacci search, Basic descent methods, Conjugate direction and Newton's methods

Constrained optimization of functions of several variables, Lagrange Multiplier method, Karush-Kuhn-Tucker theory, Constraint Qualifications, Convex optimization, Interior point methods for inequality constrained optimization, Merit functions for constrained minimization, logarithmic barrier function for inequality constraints, A basic barrier-function algorithm, Perturbed optimality conditions.

Quadratic optimization: Wolfe method, Beale's Method, applications of quadratic programs in some domains like portfolio optimization and support vector machines, etc.

Practice of optimization algorithms using MATLAB.

Text Books:

1. Edwin K. P. Chong and Stanislaw H. Zak: An Introduction to optimization, 4th Edition, John Wiley & Sons, New York, (2013).
2. Singiresu. S. Rao: Engineering Optimization: Theory and Practice, John Wiley & Sons, (2009).
3. J. Nocedal and S. J. Wright, Numerical Optimization, Springer Verlag, (1999).
4. D.P. Bertsekas, Dynamic programming and Optimal Control, Athena Scientific, Belmont, 4th Edition, (2012).
5. S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, New York, (2004).

Reference Books:

1. O.L. Mangsarian: Nonlinear Programming, SIAM, (1994).
2. D. G. Luenberger, Linear and Nonlinear Programming, 2nd Edition, Kluwer, (2003).
3. M.S. Bazaraa, H.D. Sherali and C.M. Shetty: Nonlinear Programming: Theory and Algorithms, John Wiley and Sons, New Jersey, (2006).

<u>Departmental Electives for Semester VI</u>

Course Name	**Discrete Differential Geometry**
Course Number	MA452 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	This course will be self-contained. Some familiarity with multivariable calculus is required.

Discretization of Surfaces (Special Classes and Parametrizations): Surfaces from Circles, Minimal Surfaces from Circle Patterns: Boundary Value Problems, Examples, Designing Cylinders with Constant Negative Curvature, The Discrete Green's Function.

Curvatures of Discrete Curves and Surfaces: Curves of Finite Total Curvature, Convergence and Isotopy Type for Graphs of Finite Total Curvature, Curvatures of Smooth and Discrete Surfaces.

Geometric Realizations of Combinatorial Surfaces: Polyhedral Sur- faces of High Genus, Necessary Conditions for Geometric Realizability of Simpli- cial Complexes, Enumeration and Random Realization of Triangulated Surfaces, Heuristic Methods for Finding Realizations of Surfaces.

Geometry Processing and Modeling with DDG: What Can We Mea- sure?, Convergence of the Cotangent Formula: An Overview, Discrete Differen- tial Forms for Computational Modeling, A Discrete Model of Thin Shells.

Discrete Morse Theory: Basic definitions, Simplicial collapses, Discrete vector fields, A graph-theoretic point of view, Homotopy type, Sphere theorems, Canceling critical cells, Homology, First case: 2-dimensional complexes, From point data to discrete Morse functions, Optimality, Applications.

Textbook:

1. Bobenko, Alexander I., Schroder, P., Sullivan, John M., and Ziegler, Gu¨nter M. (2008), Discrete differential geometry. Birkhauser Verlag AG.
2. Bobenko, Alexander I. and Yuri B. Suris (2008), ”Discrete Differential Geometry”, American Mathematical Society.
3. Forman, Robin (2002), “A user's guide to discrete Morse theory”. S´eminaire Lotharingien de Combinatoire. 48: Art. B48c, 35 pp.
4. Knudson, P. Kevin (2015), Morse Theory: Smooth and Discrete, World Scientific.

Course Name	**Introduction to Mathematical Biology**
Course Number	MA332
Course Credit	3 – 0 – 0 – 6
Prerequisite	

Motivation. Introduction to biological systems and their mathematical representation. Basic mathematical tools such as Linearization, qualitative solution of difference and differential equations, stability, nonlinear dynamics.

Mathematical modeling in ecology: Single species models (continuous and discrete), multi species models: Prey-predator models, Competition models, cooperation models, harvesting in population, fisheries models, optimal harvest.

Mathematical modeling of infectious diseases: Introduction to disease modeling, compartmental models, Basic models- SI, SIS, SIR, SIRS etc. Models with demography, Vaccination models, Ross Malaria Model.

Mathematical models in cellular biology such as HIV in vivo dynamics, Models in immunology.

Parameter estimation.

Textbook:

1. M. Kot, Elements of Mathematical Ecology, Cambridge University Press, 2012.
2. M.Y. Li, An introduction to mathematical modeling of infectious diseases, Springer, 2018.

Reference:

1. J.D. Murray, Mathematical Biology Vol I & II, Springer, 2001

Departmental Electives for Semester VII

Course Name	**Algebraic Topology**
Course Number	MA527 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Algebra (MA427) and Topology (M 422)

Homotopic maps, homotopy type, retraction and deformation retract. Fundamental groups. Computation of fundamental groups of n-spheres, the cylinder, the torus, and the punctured plane, the Mobius strip, projective plane and the Klein bottle. Applications: the Brouwer fixed-point theorem, the fundamental theorem of algebra.

Covering projections, the lifting theorems, relations with the fundamental group, classification of covering spaces, universal covering space. The Borsuk-Ulam theorem, free groups, Seifert Van Kampen theorem and its applications.

Text and References:

1. F. H. Croom, Introduction to Algebraic Topology, Springer, 2014.
2. M. A. Armstrong, Basic Topology, Springer-Verlag, 1983.
3. W. S. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, 2007.
4. J. J. Rotman, An Introduction to Algebraic Topology, Springer-Verlag, 1988.
5. E. H. Spanier, Algebraic Topology, Springer-Verlag, 1989.

Course Name	**Control Theory**
Course Number	MA531 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Mathematical models of control systems, State space representation, Autonomous and non-autonomous systems, State transition matrix, Solution of linear dynamical system.

Transfer function, Realization, Controllability, Kalman theorem, Controllability Grammian, Control computation using Grammian matrix, Observability, Duality theorems, Discrete control systems, Controllability and Observability results for discrete systems.

Companion form, Feedback control, State observer, Liapunov stability, Stability analysis for linear systems, Liapunov theorems for stability and instability for nonlinear systems, Stability analysis through Linearization, Routh criterion, Nyquist criterion, Stabilizability and detachability.

State feedback of multivariable system, Riccatti equation, Introdction to Calculus of variation, Euler- Hamiltonian equations, Computation of optimal control for linear systems.

Texts / References

1. S. Barnett, Introduction to Mathematical Control Theory, Clarendon press Oxford 1975
2. R. V. Dukkipati, Control Systems, Narosa 2005
3. I. J. Nagrath and M. Gopal, Control System Engineering, New Age international 2001.
4. B. Datta, Numerical Methods for Linear Control Systems, Academic press Elsevier, 2004.

Course Name	**Graph Theory**
Course Number	MA533 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Basic notions of Graph theory, Eulerian graph, Bipartite graph, Adjacency and Incidence matrices, Graph isomorphism, Bipartite graph and matrices, Diameter and eigenvalues, Trees, Leaves, Forests, Counting labelled trees, Spanning subgraphs,

Minimum spanning trees and Kruskal's algorithm, Colouring graphs, Colouring Trees and Cycles, Polya Theory, The Marriage theorem, Matching in general graph, Connectivity, Planar graphs, Euler's formula, The five colour theorem, Edges and cycles, Edge colouring, Hamiltonian cycles, Regular graphs, Eigen values of regular graphs, Diameter of regular graphs, Ramanujan graphs.

Text and References:

1. Reinhard Diestel, Graph Theory, Graduate Texts in Mathematics, Springer, 1997.
2. B. Bollobas, Graph theory an introductory course, GTM 63, Springer-Verlag, New york, 1979.
3. J. Bondy and U S R Murty, Graph Theory, Springer, 2014.
4. J. H. van Lint and R.M. Wilson, A course in combinatorics, Cambridge University press, 1992.
5. S. M. Cioaba and M. Ram Murty, A first Course in Graph Theory and Combinatorics, TRIM, Hindustan Book Agency, 2009.

Course Name	**Introduction to Coding Theory**
Course Number	MA535 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Algebra (MA 427)

Polynomial rings over fields, Extension of fields, Computation in GF(q), n-th roots of unity, Vector space over finite fields.

Error correcting codes: Binary group codes, Hamming codes, Linear block codes, The structure of cyclic codes, Quadratic residue codes, Reed Mueller codes, Simplex codes.

Nonlinear codes, Golay, Hadamard, Justeen, Kerdock, Nordstorm-Robinson codes, First and Second order Reed-Mueller codes, t-designs, steiner systems, Weight distribution of codes.

Generalized BCH codes. Self-dual codes and invariant theory, Covering radius problem, Convolutional codes, LDPC codes, Turbo codes.

Text and References:

1. Ron Roth, Introduction to Coding Theory, Cambridge University Press, 2006.
2. J. H. van Lint, Introduction to Coding Theory, Springer, 1999.
3. Raymond Hill, A First Course in Coding Theory (Oxford Applied Mathematics and Computing Science Series), Clarendon Press, 1986.

Course Name	**Mathematical Modeling**
Course Number	MA539 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

System of differential equations; Linear and nonlinear stability; Basic idea of bifurcation; some illustrations with help of computer programming

Introduction to modeling; Elementary mathematical models and General modeling ideas; General utility of Mathematical models, Role of mathematics in problem solving; Concepts of mathematical modeling; System approach; formulation, Analyses of models; Pitfalls in modeling;

Illustrations models such as Population dynamics, Traffic Flow, Social interactions, Viral infections, Epidemics, Finance, Economics, Management, etc. (*The choice and nature of models selected may be changed with mutual interest of lecturer and students.*)

Introduction to probabilistic models.

Text & References:

1. D. N. P. Murthy, N. W. Page, Ervin Y. Rodin, Mathematical modelling: a tool for problem solving in engineering, physical, biological, and social sciences, Pergamon Press, 1990.
2. W. E. Boyce and R.C. DiPrima, Elementary Equations and Boundary Value Problems, 7th Edition, Wiley, 2001.
3. J. D. Murray, Mathematical Biology, Vol I, 3rd Ed, Springer, 2003.
4. Wei-Bin Zhang, Differential equations, bifurcations, and chaos in economics, Series on Advances in Mathematics for Applied Sciences, Vol 68, World Scientific, 2005.

Course Name	**Statistical Inference**
Course Number	MA541 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Estimation problems and sufficiency, Factorization method for sufficiency, Lehmann-Scheffe method, minimal sufficiency, exponential families, unbiased estimators and properties, mean square error, Rao-Blackwell Theorem, method of moments estimators, maximum likelihood estimation, goodness criteria, Cramer-Rao inequality, Bhattacharya bounds, equivariance principal and applications, confidence intervals, pivotal quantities, optimal confidence intervals.

Tests of hypotheses, simple and composite hypotheses, error probabilities, significance probabilities, size of a test, monotone likelihood ratio property, Neyman-Pearson Lemma, uniformly most powerful tests, uniformly most powerful unbiased tests, likelihood ratio tests, chi-square tests.

References:

1. R. L. Berger and G. Casella, Statistical Inference, Duxbury Advanced Series, Second Edition, 2007.
2. A. M. Mood, F. A. Graybill and D. C. Boes, Introduction to the Theory of Statistics, Tata McGraw-Hill, 2009.
3. V. K. Rohatgi & A. K. Md. E. Saleh, An Introduction to Probability and Statistics. John-Wiley, Second Edition, 2009.
4. E. J. Dudewicz & S. N. Mishra, Modern Mathematical Statistics. John Wiley, 1988.

Course Name	**Cryptography**
Course Number	MA515 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	

Congruences, Quadratic congruence, Power residues, Higher power residues and reciprocity theorems, Algorithm to solve quadratic equations in Z_m. Finite fields, construction and examples, factorizations of polynomials over finite fields, algorithm to determine irreducible polynomials of degree n over Z_m.

Classical cryptosystems, DES-security and generalizations, Prime number generation. Public Key Cryptosystems of RSA, Rabin, etc. their security and cryptanalysis. Primality, factorization and quadratic sieve, efficiency of other factoring algorithms. Diffie-Hellman key exchange, Discrete logarithm problem in general and on finite fields. Cryptosystems based on discrete logarithm problem such as Massey-Omura cryptosystems. Algorithms for finding discrete logarithms and their analysis.

Elliptic curves-basic facts, elliptic curves over R, C, Q, finite fields, Group Law, elliptic curve cryptosystems, analogue of ElGamal on elliptic curves, Primality testing and factorizations.

Text Books:

1. Neal Koblitz, *A Course in Number Theory and Cryptology*, Graduate Texts in Mathematics, Springer Verlag, New York (1987).
2. Jonathan Katz and Yehuda Lindell, *Introduction to Modern Cryptography*, *2nd edition*, CRC Press, New York (2014).

Reference Books:

1. D. Bressoud, *Factorization and Primality Testing*, Undergraduate Texts in Mathematics, Springer (1989).
2. W. Trappe and L. Washington, *Introduction to Cryptography and Coding Theory*, Pearson Int. Edition, (2006).
3. Niven and T. Zuckermann, *An Introduction to the Theory of Numbers*, 5th Wiley Eastern (2008).
4. D.E. Burton, *Elementary Number Theory*, Tata McGraw-Hill Edu. Pvt. Ltd., 7th Edition (2015).

Course Name	**Fields and Galois theory**
Course Number	MA543 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	

Fields, field extensions, field automorphisms, Algebraic extension, minimal polynomials, splitting fields, algebraic closure, separable and normal extensions.

Galois extension, Galois groups, The fundamental theorem of Galois theory, finite fields, cyclotomic extensions, composite and simple extensions, extensions over rationals.

Galois group of polynomials, symmetric functions, discriminant, Galois group of quadratic, cubic and quartic polynomials, solvable extensions, radical extensions, solution of polynomial equations in radicals, insolvability of the quantic.

Text Books:

1. D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley & sons, Inc., 2nd Edition, 1999.
2. I. Stewart: Galois Theory, Academic Press, edition 1989.

Reference Books:

1. Emil Artin: Galois Theory, University of Notre Dame Press, 1971.
2. S. Lang: Algebra, III Edition, Springer, 2004.

Course Name	**Discrete Structures**
Course Number	MA503 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Mathematical Logics, Sets, Relations and Mappings:
Statements, Logical connectives, Truth tables,Equivalence, Inference and deduction, Predicates, Quantifiers. Relations, Equivalence relations, PartialOrder relations and lattices, Chains, Antichains,
Dilworth's Theorem, Composition of mappings, one-oneand onto mappings, Pigeonhole Principle,
Counting techniques, Countable and Uncountable sets.

Semigroups and Monoids:
Semigroups, Monoids, Subsemigroups/monoids, Congruence and quotientsemigroups/monoids, Homomorphism, isomorphism and the basic isomorphism theorem.

Graph Theory:
Basic concepts of graphs, directed graphs and trees, Adjacency and incidence matrices,Spanning trees, Matchings and Coverings, Hall's condition, Graph Coloring, Planar Graphs, Eulerian andHamiltonian graphs.

Combinatorics:
Permutation, Combination, Principle of inclusion and exclusion, Recurrence relations,Generating functions

Boolean Algebra:
Boolean algebra and their various identities, Homomorphisms and isomorphisms,Atoms and the
Stone's theorem (finite case), Boolean functions, their simplification.

Texts / References

1. C.L. Liu, Elements of Discrete Mathematics, McGraw-Hill, 1985
2. D.B. West, Introduction to Graph Theory, 2nd ed., 2001, PHI Learning
3. P.J. Cameron, Combinatorics: Topics, Techniques, Algorithms, First Ed. 1994, Cambridge University Press
4. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to the Theory of Numbers, 1991, John Wiley and sons.
5. P.R. Halmos, Naive Set Theory, UTM, Springer, 1

Course Name	**Introduction to Algebraic Geometry**
Course Number	MA545 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Affine algebraic Sets, Affine Varieties : Hilbert's Nullstellensatz, Polynomial and Rational functions

Projective Algebraic Sets, Projective Varieties: Projective Space and Rational Maps

Tangent Spaces, Smooth and Singular Points, Dimension of a Variety

Plane Curves, Intersection Multiplicity, Cubic Curves, Elliptic Curves, Cubic Surfaces and rationality

Theory of plane Curves: Divisors on Curves, Degree of a principal divisor, Bezout's Theorem, Projective Embeddings of Curves

Textbook:

1. Klaus Hulek: Elementary Algebraic Geometry, STML20, AMS, 2003

References:

2. Thomas Garrity: Algebraic Geometry: A Problem Solving Approach, STML66, AMS,2013
3. Keith Kendig: Elementary Algebraic Geometry,GTM44, Springer,NY, 1977
4. C. Musili: Algebraic Geometry for Beginners (TRIM),HBA, 2001
5. Justin R Smith: Introduction to Algebraic Geometry, Createspace Independent Pub, Dover reprint, 2014
6. S S Abhyankar: Algebraic Geometry For Scientists And Engineers, AMS, 1990
7. Daniel Perrin: Algebraic Geometry An Introduction, Universitext, Springer, 2008

Departmental Electives for Semester VIII

Course Name	**Differential Manifolds**
Course Number	MA526 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Real Analysis (MA 425) and Topology (MA 422)

The derivative, continuously differentiable functions, the inverse function theorem, the implicit function theorem.

Topological manifolds, partitions of unity, imbedding and immersions, manifolds with boundary, submanifolds.

Tangent vectors and differentials, Sard's theorem and regular values, Local properties of immersions and submersions.

Vector fields and flows, tangent bundles, Embeddings in Euclidean spaces, smooth maps and their differentials.

Smooth manifolds, smooth manifolds with boundary, smooth submanifolds, construction of smooth functions, classical Lie groups.

Text and References:

1. J. M. Lee, Manifolds and Differential Geometry, AMS, GSM, 2014.
2. G. E. Bredon, Topology and Geometry, Springer-verlag, 1993.
3. A. Kosinski, Differential Manifolds, Academic Press, 1992.
4. J. R. Munkres, Analysis on Manifolds, Addison-Wesley Publishing Company, 1991.
5. M. Spivak, A Comprehensive Introduction to Differential Geometry I, Publish or Perish, 1979.

Course Name	**Differential Topology**
Course Number	MA528 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Real Analysis (MA425) and Topology (MA 422)

Manifolds and smooth maps: Derivatives and tangents, implicit and inverse function theorems. Immersions, submersions, transversality, homotopy and stability, Sards Theorem and Morse functions, embedding manifolds in Euclidean spaces.

Transversality and Intersection: Manifolds with boundary, transeversality, Intersection theory mod 2, Winding number and the Jordan-Brouwer separation theorem, Borsuk-Ulam theorem.

Text and References:

1. J. M. Lee, Manifolds and differential geometry, AMS, GSM , 2014
2. V. Guillemin and A. Pollack, Differential Topology, Prentice Hall, New Jersey, 1974.
3. M. Spivak, Calculus on manifolds, Benjamin, 1965.

Course Name	**Fuzzy Sets and Systems**
Course Number	MA530 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	

Introduction, Uncertainty, Imprecision and vagueness, Brief history of fuzzy logic, Fuzzy sets and systems, Fuzzy systems in commercial products, Research fields in fuzzy theory.

Basic Concepts of fuzzy sets, Fuzzy logic, Types of membership functions, Basic concepts (support, singleton, height, a-cut projections), Zadeh's extension principle, Operations on fuzzy sets, S-and T- Norms, Fuzzy measures, Probability and Possibility measures, Linguistic variables and hedges, Membership function design.

Fuzzy inference methodologies, Graphical techniques of inference, Fuzzyifications/ Defuzzification, Classical relations, Fuzzy relations, Fuzzy to crisp conversions.

Fuzzy systems and algorithms, Approximate reasoning, Applications of fuzzy Sets in management, decision making, medicine and computer Science. Case Studies in Various Domain.

Texts:

1. S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 2nd Ed, Prentice Hall, 2003.
2. H. J. Zimmermann, Fuzzy Set Theory and Its Applications, 2nd Ed., Kluwer Academic Publishers, 1996.
3. D. Dubois and H. Prade, Fuzzy Sets and Systems: Theory and Applications, Academic Press, 1980.

References:

1. E. Charniak and D. McDermott, Introduction to Artificial Intelligence, Addison-Wesley, 1985.
2. E. Rich, Artificial Intelligence, McGraw-Hill, 1983.
3. P. H. Winston, Artificial Intelligence, Addison Wesley, 1993.
4. J. Yen and R.Langari, Fuzzy Logic Intelligence, Control, and Information, Pearson Education, 2005.
5. T. J. Ross, Fuzzy Logic with Engineering Applications, McGraw-Hill, 1997.
6. J. Kacprzyk, Multistage Fuzzy Control, Wiley, 1997.

Course Name	**Introduction to Biomathematics**
Course Number	MA532 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	

Course Dynamics:

The course will comprise of class room lectures, take home assignments based on class room lectures as well as reading assignments, and a mathematical modeling project with a final report and/or presentation of the work and final written exams. The weightage of different component will be different.

Syllabus:

Mathematical modeling: Role of mathematics in problem solving, Introduction to mathematical modeling and its basic concepts- system description and characterization, model formulation, validation and analysis of models, Pitfalls in modeling.

Population Dynamics: Deterministic models in population dynamics, Stochastic birth-death models.

Models in ecology: Predator-prey models, Spatio-temporal models- diffusion processes, fisheries models.

Models at molecular level: HIV in vivo model, immune response models, Cancer models.

Modeling disease: Infectious disease models, Models for non-communicable diseases (NCDs),

Models for public health: Diseases control and interventions, Optimal control, Cost optimization.

Computational: Parameter estimation, network models.

Text & References:

1. N. F. Britton, Essential Mathematical Biology, SUMS, Springer
2. F. Brauer and C. Castillo-Chavez, Mathematical models in population biology and epidemiology, Springer, 2012.
3. D. N. P. Murthy, N. W. Page, Ervin Y. Rodin, Mathematical modelling: a tool for problem solving in engineering, physical, biological, and social sciences, Pergamon Press, 1990.
4. J. D. Murray, Mathematical Biology Volume I, 3rd Ed, 2003.
5. F. C. Hoppensteadt, Mathematical methods of population biology. Cambridge: Cambridge Univ. Press, 1982.

Course Name	**Operators on Hilbert Spaces**
Course Number	MA534 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Functional Analysis (MA 521)

Adjoints of bounded operators on a Hilbert space, Normal, self-adjoint and unitary operators, their spectra and numerical ranges.

Compact operators on Hilbert spaces, Spectral theorem for compact self-adjoint operators, Application to Sturm-Liouville Problems.

Texts / References

1. J. B. Conway, A Course in Functional Analysis, 2nd ed., Springer, Berlin, 1990.
2. C. Goffman and G. Pedrick, First Course in Functional Analysis, Prentice Hall, 1974.
3. I. Gohberg and S. Goldberg, Basic Operator Theory, Birkhauser, 1981.
4. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
5. B. V. Limaye, Functional Analysis, 2nd ed., New Age International, New Delhi, 1996.
6. M. T. Nair, Functional Analysis: A First Course, PHI Pvt. Ltd, 2004.

Course Name	**Rings and Modules**
Course Number	MA536 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Algebra (MA 427)

Modules, sub modules, quotient modules and module homo morphisms, Generation of modules, direct sums and free modules.

Tensor products of modules; Exact sequences, projective modules.

Finitely generated modules over principal ideal domains, invariant factors, elementary divisors, finitely generated abelian groups and linear transformations.

Ascending Chain Condition and Descending Chain Condition, Noetherian rings and modules, Hilbert basis theorem, Primary decomposition of ideals in Noetherian rings.

Radicals: Nil radical, Jacobson radical and prime radical.

Localization of rings and modules.

Texts

1. C. Musili, Introduction to Rings and Modules, Narosa Pub. House, New Delhi, Sec. Edition, 2001.

2. J. A. Beachy, Introduction to Rings and Modules, London Math. Soc., Cam. Univ. Press, 2004.

References

1. M. F. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison Wesley, 1969.

2. D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.

3. N. Jacobson, Basic Algebra I and II, 2nd Ed., W. H. Freeman, 1985 and 1989.

4. S. Lang, Algebra, 3rd Ed., Springer (India), 2004.

Course Name	**Statistical Decision Theory**
Course Number	MA538 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Decision theoretic estimation problems, loss functions, Bayes procedures, proper and non-informative prior distributions, posterior distributions, admissible estimators, equivalent rules, minimax estimators, complete class rules, minimal complete class, illustrations, Uniformly Minimum Variance Unbiased Estimator and completeness property, Stein phenomenon, truncated parameter space estimation problems, equivariance of decision rules, location-scale groups of transformations, minimum risk equivariant rules, Bayesian credible intervals, highest posterior density intervals.

References

1. T. S. Ferguson, Statistical Decision Theory, Academic Press, 1967.
2. E. L. Lehmann, Theory of Point Estimation, Springer, Second Edition, 1998.
3. J. O. Berger, Statistical Decision Theory and Bayesian Analysis, Springer, Second Edition, 1993.

Course Name	**Wavelets Transform**
Course Number	MA540 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Various Transforms: Fourier Transforms, Poisson's Summation Formula, The Shannon Sampling Theorem, Heisenberg's Uncertainty Principle, The Gabor Transform, The Zak Transform, The Wigner-Ville Distribution, Ambiguity Functions, The Ambiguity Transformation.

Wavelet Transforms: Continuous Wavelet Transforms, Basic Properties, The Discrete Wavelet Transforms, Orthonormal Wavelets, Multiresolution Analysis and Construction of Wavelets, Properties of Scaling Functions and Orthonormal Wavelet Bases, Construction of Orthonormal Wavelets, Daubechies' Wavelets and Algorithms, Discrete Wavelet Transforms and Mallat's Pyramid Algorithm, Newland's Harmonic Wavelets, Properties of Harmonic Scaling Functions, Wavelet Expansions and Parseval's Formula.

Application: Solutions of ODEs and PDEs by using wavelets.

Text:

1. Lokenath Debnath, Wavelet Transforms and Their Applications, Springer Science+Business, Media, New York, 2002.

Reference:

1. Ülo Lepik, Helle Hein, Haar Wavelets With Applications, Springer, 2014.
2. K. P. Ramachandran, K. I. Resmi, N. G. Soman, Insight into Wavelets: From Theory to Practice, 3rd ed. PHI, 2010.
3. C. K. Chui, An Introduction to Wavelets, Academic Press, 1992.
4. Daubechies, Ten Lectures on Wavelets, SIAM Publication, Philadepphia, 1992.

Course Name	**Fuzzy sets and Artificial Intelligence**
Course Number	MA508 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Basic Concepts of fuzzy sets, Fuzzy logic, Types of membership functions, Structure of algebra of fuzzy sets, Basic concepts (support, singleton, height, α -cut projections), Zadeh's extension principle, Operations on fuzzy sets, T- norms and T- conorms, Fuzzy complement, Fuzzy measures, Probability and Possibility measures, Linguistic variables and hedges, Membership function design.

Classical relations, Fuzzy relations, Fuzzy to crisp conversions, Fuzzy inference methodologies, Graphical techniques of inference, Fuzzyifications/ Defuzzification, Introducing higher order fuzzy sets.

Fuzzy systems and algorithms, Approximate reasoning, Applications of fuzzy Sets in management, decision making, medicine and computer Science.

Introduction to Artificial Intelligence, Production System and Artificial Intelligence, Lambda expression, Fault locate and fault detect system, Logic of atleast-atmost, Decision making, Game playing, Theory of evidence, Conceptual dependency, Knowledge Bases and Expert Systems, Neuro Fuzzy Approaches, Case Studies in Various Domain.

Text:

1. S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 2nd Ed, Prentice Hall, 2003.
2. H.J.Zimmermann, Fuzzy Set Theory and Its Applications, 2^{nd} Publishers, 1996.
3. D.Dubois and H. Prade, Fuzzy Sets and Systems: Theory and Applications, Academic Press, 1980.
4. P. Klement, Triangular Norms. London: Kluwer Academic Press, 2000.
5. H T. Nguyen, E A. Walker, Fuzzy Logic. New York: Chapman and Hall, 2000.

Reference:

1. E. Charniak and D. McDermott, Introduction to Artificial Intelligence, Addison-Wesley, 1985.
2. E. Rich, Artificial Intelligence, McGraw-Hill, 1983.
3. P. H. Winston, Artificial Intelligence, Addison Wesley, 1993.
4. J.Yen and R.Langari, Fuzzy Logic Intelligence, Control, and Information, Pearson Education, 2005.
5. T.J.Ross, Fuzzy Logic with Engineering Applications, McGraw-Hill, 1997.
6. J.Kacprzyk, Multistage Fuzzy Control, Wiley, 1997.

Course Name	**Introduction to Homological Algebra**
Course Number	MA544
Course Credit	3 – 0 – 0 – 6
Prerequisite	

Review of modules, homomorphism, Free modules, Direct product and direct sum of modules, Hom and Tensor product of modules, exact sequences.

Local rings, algebras, graded rings and graded modules, polynomial rings.

Categories and functors, exact functors, injective, projective and flat modules, complexes and homology modules, resolution of a module, Koszul complex.

Derived functor: construction and uniqueness, the functors Ext and Tor, Projective, injective and global dimension, projective dimension over a local ring.

Regular sequence, depth, Auslander-Buchsbaum formula.

Text Books:

1. Balwant Singh: Basic Commutative Algebra, World Scientific Publishing Company (2011).

Reference Books:

1. M. F. Atiyah and I. G. MacDonald: Introduction to commutative Algebra, Addison-Wesley Series in Mathematics, Westview Press (1994).
2. Charles A. Weibel: An introduction to Homological Algebra, (Series Title: Cambridge Studies in Advanced Mathematics), Cambridge University Press (1995).
3. David Eisenbud : Commutative Algebra with a view towards Algebraic Geometry, Springer-Verlag New York (1995).
4. Joseph Rotman : An introduction to Homological Algebra, (Series Title: Universitext), Springer, Second edition (2009).